

Linking the Computerized Severity Index (CSI) to Coded Patient Findings in the HELP System Patient Database

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The Computerized Severity Index (CSI) is a commercially available scoring system for hospital inpatients. Trained abstractors review the patient's paper medical record and enter the diagnoses and relevant physiological facts. The HELP (Health Evaluation Through Logical Processing) System at LDS Hospital stores patient data in discrete codes. We believe that HELP's coded patient database may drive an automatic version of CSI without the need for manual input. This descriptive study examines the nature and depth of the HELP System patient findings needed to implement an automatic CSI.

INTRODUCTION

The long term goal of the authors is to completely automate CSI as an application in the HELP System using the LDS Hospital patient database. The first step in this process was to correlate the data elements required by CSI with the data elements already defined in the HELP data dictionary [1]. The second step, and the purpose of this study, was to identify which data elements are captured in the electronic medical record, and which elements are not. The second step is distinguished from the first by the latter's examination of data elements *used clinically* as opposed to data elements simply *defined* in the HELP System but not used clinically. The results presented in this paper suggest that there is adequate clinical data in the electronic medical record to warrant further efforts to develop an automatic version of CSI.

The third step of the process will involve writing an interface between the HELP System and CSI. The correspondence between the data elements in HELP and CSI is not one-to-one; therefore, the interface program will have to encode logic that determines whether data elements in the computerized patient database are equivalent to the data elements needed by CSI. The final step of the project will compare the severity scores produced by the automated version of CSI with the scores from manual chart review. If the absence of patient data elements adversely affects the performance of CSI, we plan to develop tools to capture the missing data.

SEVERITY INDEXES

Severity of illness indexes for hospitalized patients have been the subject of investigation for

more than 10 years. Such indexes have been used to predict mortality [2,3], hospital length of stay [3], cost of hospitalization, and variation in cost among patients with the same DRG (Diagnostic Related Group) [4,5]. Severity of illness indexes have also been used in quality assurance activities [6], and could be used to stratify patients entering clinical trials.

COMPUTERIZED SEVERITY INDEX (CSI)

CSI was developed by Susan Horn, PhD, and coworkers at Johns Hopkins University [3,7]. The data required by CSI include physiological attributes such as vital signs, physical exam findings, and laboratory results. CSI uses relatively few historical patient findings, and almost no treatment or intervention facts. CSI maps each ICD-9-CM principal and secondary diagnosis into 1 of 827 matrices. The data elements for each matrix determine a severity score from 1 (normal or mild symptoms or signs) to 4 (catastrophic symptoms or signs).

Each matrix represents a group of closely related ICD-9-CM diagnoses. Table 1 is a partial listing of the matrix for all the ICD-9-CM diagnoses applied to the various types of viral and bacterial pneumonia. Each matrix is comprised of submatrices which independently contribute to the score for that matrix. In turn, each submatrix is comprised of indicators, which are groups of patient descriptors, such as dyspnea and blood pressure. Indicators are subdivided into bins to which severity scores are applied. For example, the indicator dyspnea is further decomposed to dyspnea on exertion, dyspnea at rest, and apnea, each representing an increasing severity score.

The indicator with the highest score in a submatrix determines the score of that submatrix. Related indicators, such as low heart rate and low blood pressure, are grouped into the same submatrix where only one of them will affect the severity score. The use of submatrices is an attempt to prevent correlated information from unduly affecting the severity score. The two submatrices with the highest scores determine the score for that matrix. This process is repeated for each of the secondary diagnoses.

A given indicator may be used to determine the severity score of one diagnosis only. For example, if a patient has both pneumonia and congestive heart

Table 1 CSI matrix for pneumonia (a partial listing)

CSI Level 1	CSI Level 2	CSI Level 3	CSI Level 4
Submatrix: Blood pressure and pulse			
Indicator: Lowest systolic blood pressure			
Bin 1: ≥ 81 mmHg	Bin 2: 71-80	Bin 3: 61-70	Bin 4: ≤ 60
Indicator: Lowest heart rate			
Bin 1: ≥ 51 beats/min	Bin 2: 41-50	Bin 3: 31-40	Bin 4: ≤ 30
Submatrix: Arterial blood gases			
Indicator: Highest pH			
Bin 1: ≤ 7.45	Bin 2: 7.46-7.50	Bin 3: 7.51-7.60	Bin 4: ≥ 7.61
Indicator: Lowest pO ₂			
Bin 1: ≥ 50 mmHg			Bin 2: ≤ 50
Indicator: Lowest pH			
Bin 1: ≥ 7.35	Bin 2: 7.25-7.34	Bin 3: 7.10-7.24	Bin 4: ≤ 7.09
Submatrix: Dyspnea and stridor			
Indicator: Dyspnea			
Bin 1: no dyspnea	Bin 2: on exertion	Bin 3: at rest	Bin 4: apnea
Indicator: Stridor			
Bin 1: no stridor	Bin 2: stridor		

Table 2 PTXT codes associated with 2 example bins

8-byte PTXT code	Text associated with PTXT code
Indicator: Lowest systolic pressure (All bins use the same PTXT codes: value " ____ " determines bin)	
004.000.001.000.002.000.000.016	Automatic cuff systolic pressure: ____
004.000.001.000.005.005.000.016	Automatic cuff mean systolic pressure: ____
007.001.001.002.002.001.000.000	Manual systolic pressure: ____
007.001.001.002.002.024.000.000	Manual mean systolic pressure: ____
028.001.060.002.014.005.000.000	Supine systolic pressure: ____
028.001.060.002.014.020.000.000	Sitting systolic pressure: ____
028.001.060.002.014.040.000.000	Standing systolic pressure: ____
Indicator: Dyspnea Bin 3: At rest	
036.001.003.002.039.002.000.000	Respiratory therapist: labored breathing
036.001.003.002.039.004.000.000	Respiratory therapist: substernal retractions
036.001.003.002.039.005.000.000	Respiratory therapist: intercostal retractions
036.001.003.002.039.006.000.000	Respiratory therapist: grunting
203.001.010.003.003.003.002.000	Nurse charting: labored breathing
203.001.010.003.003.003.003.000	Nurse charting: purse-lipped breathing
203.001.010.003.003.003.010.000	Nurse charting: dyspneic/short of breath
203.001.010.003.003.003.011.000	Nurse charting: dyspneic at all times
203.001.010.003.003.003.012.000	Nurse charting: nocturnal dyspnea
203.001.010.003.003.003.013.000	Nurse charting: dyspnea at rest
203.001.010.003.003.003.015.000	Nurse charting: dyspnea when supine
203.001.010.003.003.003.017.000	Nurse charting: dyspnea without oxygen

failure, dyspnea may contribute to the severity score for one or the other diagnosis but not both. If several matrices use the same indicator, CSI will use the indicator in the matrix to which it contributes the highest severity score.

The CSI algorithm then considers the interaction of all the patient's diagnoses and eliminates diagnoses which arise from the same pathological condition. For example gastrointestinal hemorrhage due to a gastric neoplasm is scored under one or the other diagnosis, but not both. Each indicator bin may be scored differently in each matrix in which it is used. A fever of 39 degrees may be a score 2 in the pneumonia matrix, but the same temperature is a score 3 in leukemia. The patient's diagnoses will determine which matrix or matrices are used.

After the CSI user enters the principal and secondary diagnoses for a hospital stay, the personal computer-based CSI program inspects the matrices into which those diagnoses are mapped. The indicators and bins from all the involved matrices are listed on the computer's screen. After reviewing the patient's paper chart, trained abstractors register the presence of or absence of the bin criterion, or, for continuous indicators, the value of the indicator presented. The program then calculates the overall patient severity score and prints a report detailing the indicators and bins used to arrive at that score. Abstractors require about 15 minutes per patient to review a paper chart and enter findings. We believe that the patient data stored in the computerized medical record of the HELP System at LDS Hospital may be able to automatically provide the patient findings needed to calculate severity of illness without the need for manual chart review.

THE HELP SYSTEM

Elements of the HELP System have been under development at LDS Hospital, a 520-bed tertiary care center in Salt Lake City, since 1967 [8,9]. HELP provides an integrated, computerized environment for use and development of clinical, administrative, and financial modules. An integrated expert system tool is used to support medical decision making.

HELP uses a hierarchical, numerically-based coding scheme to represent medical terms. Drug names, laboratory tests, diagnoses, admission-discharge-transfer data, physical exam findings, and nursing care plans and actions are all represented by 8-byte codes called PTXT (pronounced "P-text", for Pointer-to-TeXT) codes defined in a comprehensive data dictionary. Despite efforts to restrict new entries and discard unused PTXT codes, there are

medical terms represented by more than one PTXT code, and there are defined PTXT codes not used by any current application. This study examines which PTXT codes were actually stored in the patient database by applications in use in 1991.

LINKING CSI TO THE HELP SYSTEM

We mapped CSI data elements to defined PTXT codes [1]. On average, we found that 52% of the indicator bins for each matrix could be associated with one or more PTXT codes. Since a patient's CSI score defaults to 1 in the absence of more severe findings, we looked at a subset of the indicator bins that contributed to a severity score of 2 or more. The average proportion of indicator bins (score 2 or greater) with PTXT codes increased to 66%.

The 827 matrices in CSI are comprised of approximately 700 indicators (many indicators are used in more than one matrix). In turn, the 700 indicators are divided into 2000 bins. For 1450 bins we could find no PTXT code with the same medical concept. The remaining 550 bins were associated with approximately 1000 distinct PTXT codes. Many PTXT codes were associated with more than one bin. Table 2 shows 2 example bins with their associated PTXT codes.

RESULTS

We chose 4 matrices which represent some of the most common non-obstetric principal discharge diagnoses at LDS Hospital. The computerized database for all patients discharged in 1991 with pneumonia, congestive heart failure, acute myocardial infarction, and prostate cancer were searched for PTXT codes corresponding to CSI indicators. The results for each of the 4 diagnoses are shown in Tables 3 through 6.

These tables require explanation. Each line in Tables 3 through 6 represents a submatrix used by CSI to score that matrix. For submatrices with more than one indicator, the indicator listed is that indicator found in the greatest proportion of patients. The indicator names are listed to give the reader an idea of the type of data that would drive the automatic CSI scoring. Because patients' CSI scores default to 1 in the absence of more severe indicators, only those indicators that lead to a severity score of 2 or higher are shown.

The percentage listed is the proportion of patients with the most frequently found PTXT code for that indicator. The count column is the number of times

Table 3 364 patients with pneumonia

%	count/pt	indicator
99	6	WBC count ¹
90	23	heart rate (high)
90	23	blood pressure (low)
89	16	temperature
82	7	arterial blood gasses
32	2	chest X-ray findings
22	3	sputum characteristics
17	2	level of consciousness
0	0	cyanosis

¹ WBC = white blood cell

per patient that the corresponding PTXT code appeared in the electronic record. The denominator of the "counts/patient" column is the number of patients where that code was found at least once.

One indicator in each of Tables 5 and 6 had no PTXT codes associated with any of its bins. These indicators are noted with an "ND" (not defined). In Table 5, the CSI indicator "episodes of angina" was divided into bins which had no conceptual equivalent in PTXT codes. In Table 6, the physical exam of the prostate is usually done by a physician, and the HELP data dictionary has few PTXT codes for physician findings.

DISCUSSION

This descriptive study reveals that the *automated* CSI severity score for 4 of the most common medical diagnoses at LDS Hospital will be derived largely from 6 data areas: (1) vital signs, (2) common laboratory studies, (3) chest X-ray findings, (4) 12-

Table 4 344 patients with congestive heart failure

%	count/pt	indicator
92	20	blood pressure (low)
71	6	arterial blood gasses
50	25	urine output (low)
38	3	chest X-ray findings
24	2	12-lead ECG findings
10	2	level of consciousness
4	5	sputum characteristics
0	0	level of independence
0	0	cardiac output
0	0	degree of edema
0	0	palpitations
0	0	abn heart sounds ¹
0	0	cyanosis

¹ abn = abnormal

Table 5 466 patients with myocardial infarction

%	count/pt	indicator
99	22	temperature
96	4	CPK MB fraction ¹
96	7	WBC count ²
94	196	blood pressure (low)
53	30	urine output (low)
34	5	chest X-ray findings
6	3	level of consciousness
0	0	cardiac output
0	0	cyanosis
0	0	12-lead ECG: block
0	0	12-lead ECG: V fib ³
0	0	muffled heart sounds
ND ⁴	ND ⁴	episodes of angina

¹ CPK = creatine phosphokinase

² WBC = white blood cell

³ V fib = ventricular fibrillation

⁴ ND = not defined in PTXT code

lead ECG results, (5) fluid intake-output records, and (6) level of consciousness. At LDS Hospital some vital signs are captured directly from the monitoring equipment, and some from manual entry into the computer. Laboratory results are transferred to the database directly from the laboratory computer. Chest X-ray findings stored in the patient database come from an application program which parses the radiologists' freetext dictation. Twelve-lead ECG findings are transferred directly to the database from the Marquette MUSE ECG system. Fluid intake-output records and level of consciousness findings are entered manually into the database by nurses using the nurse charting application programs [9].

Currently nursing divisions at LDS Hospital have two different nurse charting programs. Many of the patients whose electronic records were examined were cared for on nursing divisions using the charting program with relatively few patient physical exam PTXT codes. Within the year, when all divisions are

Table 6 182 patients with prostate cancer

%	count/pt	indicator
98	6	hemoglobin
97	28	heart rate (high)
43	1	albumin
76	5	gross hematuria
0	0	bladder distention
ND ¹	ND ¹	prostate phys exam ²

¹ ND = not defined in PTXT codes

² phys = physical

updated to the same, new nurse charting program, PTXT codes derived from nursing observations may play a larger role in determining the automated (vs. manual) CSI score. Such observations include: description of chest pain, dyspnea, cyanosis, stridor, crackles on auscultation, bladder distention, etc.

Physicians' admission, progress, consultation, and discharge notes are examined manually by CSI reviewers. Currently at LDS Hospital, these dictated physician notes are stored in the database as freetext. The information in these notes is not stored as discrete PTXT codes, and as such, is not available for automatic CSI scoring. Whether the absence of this data source will diminish the accuracy of automatic CSI scoring relative to the gold standard of manual CSI scoring will not be known until automatic CSI scoring is fully implemented and validated.

Except for prostate cancer (Table 6), 3 of the 4 diagnoses considered in this study appear to have at least 7 independent indicators determining the CSI score. Because matrix scoring is based on only the two highest submatrices, it appears that having 7 indicators with associated PTXT codes will be adequate to permit automated CSI scoring. Multiple indicators should make the automatic CSI scoring robust to deficiencies in any one indicator. However, when the interaction of the patient's principal and secondary diagnoses is considered, indicators potentially usable by more than one diagnosis will have to be applied to only one of the diagnoses. Therefore, the number of independent indicators leading to each matrix's score may decrease, and the system may be less robust to database inadequacies. The magnitude of this effect must await automatic CSI development.

The 1356 patient records examined represent 6.3% of the approximately 21,500 inpatient discharges from LDS Hospital in 1991. The CSI matrices used for other medical and surgical diagnoses not presented in this study are similar to those presented in their reliance on objective, mostly numerical patient facts. Matrices, such as those used for psychiatric diagnoses, are based largely on more subjective, descriptive patient findings. We expect that the computerized database may not be adequate to support automated CSI scoring for such matrices.

CONCLUSIONS

Users of other hospital information systems may be encouraged by the results of this study which suggest that automatic CSI scoring, if validated, will be based on relatively simple, objective, easily

collected, and mostly numerical observations about the patient. Such data are more easily captured in hospital information systems than are the more descriptive elements of physician and nurse history and physical exam charting.

There appear to be enough coded patient findings stored in the HELP System database to warrant continued development of an automatic Computerized Severity Index. Our attention will now turn to the development of the logical interface between CSI and the HELP System.

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